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Int. J. Environ. Res., 8(3):551-560,Summer 2014
ISSN: 1735-6865

Multi-Criteria Decision Modeling for Environmental Assessment. An Estimation of Total Economic Value in Protected Natural Areas

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Received 14 Nov. 2013; Revised 26 Jan. 2014; Accepted 28 Jan. 2014

ABSTRACT: The conceptualization of Total Economic Value (TEV) associated with protected natural areas necessarily requires an analytical reordering that ensures a simultaneous incorporation of natural, social and economic components. Based on this purpose, the present paper uses a multi-criteria decision modeling for the economic valuation of environmental goods and services (EGS) in the Viñales National Park (PNV) based on a combination of methods such as the Analytic Hierarchy Process (AHP) and the Goal Programming (GP) with other traditional such as the income updating method. The proposed procedure allowed estimate an indicator of Total Economic Value (TEV) and its different components: Direct Use Value (DUV), Indirect Use Value (IUV), Option Value (OV), Existence Value (EV) and Bequest Value (BV). The obtained results represent a contribution from economic science to the definition of environmental policies, allocation and distribution of financial resources, as well as the design and implementation of management plans or other strategic projections.

Key words: Multi-criteria decision modeling, Analytic Hierarchy Process (AHP), Goal Programming (GP), Total Economic Value (TEV), Environmental Goods and Services (EGS)

INTRODUCTION

The multi-criteria decision modeling associated with treating of the environmental phenomena has been widely used in recent decades to order and select multiple management alternatives. Indeed, the number of possible applications of this modeling, has led to a multitude of supporting methods to the decision during all stages considered in the adoption process of the best compromise solution, among which stand out the works presented by Rodriguez-Uria *et al*., (2002), Leskinen and Kangas (2005), Caballero *et al*., (2009), Babulo *et al*., (2010), Vukicevic and Nedovic-Budic (2013), Convertino *et al*., (2013) and Pérez *et al*., (2013). Many of these efforts respond to complex problems in which its own nature goes necessarily to multiple considerations. In this sense, it highlights the use of the Analytic Hierarchy Process (AHP) in the works developed by Blancas and Guerrero (2005), Martín and Berbel (2007), Wan Ismail and Abdullah (2012) as well as the implementation of Goal Programming (GP) in Díaz-Balteiro and Romero (2004), León *et al*., (2008) and Giménez *et al*., (2013).

A vital factor in the significance of this modeling responds to its potentialities to generate and analyze different courses of action based on multiple evaluation criteria. In that sense, the studies of economic valuation of environmental goods and services (EGS), especially in protected natural areas, combine components of natural, economic and social aspects, so that multiple criteria are the rule rather than the exception. Real life is multi-criteria! (Caballero and Romero, 2006).

In this work, a modeling is used based on a combination of methods such as AHP, and the GP, multi-criteria approaches with broad applications in economics and environmental resources, with the classical income updating method, this one,

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conceptually very similar to the Net Present Value (NPV), (Aznar and Estruch, 2007; Ortuño *et al.*, 2007). The procedure allows estimating an indicator of Total Economic Value (TEV) and its vaRíous partial values as Direct Use Value (DUV), the Indirect Use Value (IUV), the Option Value (OV), the Existence Value (EV) and the Bequest Value (BV).

The research was developed in the Viñales National Park (PNV), declared by UNESCO as a Cultural Landscape of Humanity, located in the most western province of Cuba, exactly in the municipality of Viñales, Montañas de Guaniguanico sub district, occupying its center in the center – eastern portion of the Sierra de los Órganos.

MATERIALS & METHODS

In this section, the use of the multi-criteria decision modeling for the economic valuation of EGS in protected natural areas is explained, as a mathematical tool that allows the incorporation of environmental issues in the analytical framework of economical science and thus a combination of natural, social and economic components. The modeling used for this research articulates a singular procedure which steps are defined below (Aznar and Estruch, 2007):

I. The initial step consists in defining the components (DUV, IUV, OV, EV, BV) of the Total Economic Value (TEV) that are present in the Viñales National Park (PNV). Clearly, this stage has a vital significance for the development of the questionnaire to be offered to the experts, because it should be provided methodological guidelines that clearly define the components of the TEV to obtain relative judgments and thus adequate primary information. At the same time, the definition of these components allows the author determining the pivot value to be used to deduce the indicator of the TEV.

The TEV of a natural area includes both commercial and environmental provided benefits; these include direct and indirect benefits (Pearce, 1993; Campos, 1994). In this discussion, two groups of value are identified: Use Values (UV) and Non-use Values (NV). As UV, are defined those derived from the actual use of a good or service, which can be direct (DUV), for the case of a forest, hunting or wood, or indirect (IUV), as a consideration of its not compensable uses which are not directly valued by the market (Martínez *et al*., 2004).

The Option Value (OV) is defined as the value given by the society to certain environmental elements in a context of uncertainty about the possibility of future use (Azqueta and Pérez, 1997). Regarding NV, the Organization for Economic Cooperation and Development (OECD) notes that NV refers to the willingness or desire to maintain any good in existence even there is no real use, possible or planned, considering the existence of an Existence Value (EV) a Bequest Value (BV) and the altruistic value (OECD, 2002). The EV is defined as the value of knowing that there is still a component of the environment, derived from the existence of the environmental asset, whereas the BV defines who has given to an environmental good or natural resource for future generations, therefore assuming not only future technological levels but also scales of values and moral principles of those who will come after us, which intrinsically includes an altruistic concept (Pearce and Moran, 1994).

II. The next step corresponds to the selection of the experts group. In this case, the selection of these members is obtained by using the Delphi Method or experts criteria.

The utilization of the Delphi Method responds to their potentialities for structuring the group communication process, so that it is effective to allow a group of individuals, as a whole, dealing with complex problems, in addition to counting on the participant's anonymity, its controlled feedback and the response to the group in an statistic way (Linstone and Turoff, 2002).

As a premise for this process, it is adopted the methodology based on its self-assessment procedure, considering it reflects their competences (Linstone and Turoff, 2002; Crespo, 2007).

III. Once defined the experts; they are presented, by a questionnaire, pairwise comparisons to issue their judgments about the degree of importance they give to each of the TEV components. Exactly three comparisons are presented in pairs, one of them is associated with UV vs. NV, the other represents the comparisons between UV and finally the comparisons between NV are offered.

In this step, the AHP method is used to make comparisons between the different components and assign numerical values to their subjective judgments about the relative importance of each variable. To complete the mentioned questionnaire, it is used the comparisons fundamental scale proposed by Saaty (1980).

It should be noted that, considering the pairwise comparison is used only to obtain a judgment on the importance and intensity of a TEV component (DUV, IUV, OV, EV, BV) compared to other, the pRíoritization is developed regarding only this criteria, thus, the achievement of the values which make the eigenvector responds directly to the weightings given by the experts to each alternative or TEV component.

In terms of decision quality, the consistency of the judgments made by experts is verified, which constitutes one of the advantages of AHP method. In this regard, it is considered that the pRíority vector has an acceptable inconsistency when the consistency ratio (CR) is less than 10% for matrix with order higher than 4 (n Ã 4), a 5% for n = 3 and 8% for n = 4 (Saaty, 1980; Aznar and Estruch, 2007).

IV.Individual preferences obtained with the AHP method are aggregated by Weighted Goal Programming (WGP), in such way allowing obtaining an eigenvector that indicates the global weight of each TEV component.

According to this purpose, preference aggregation methodologies proposed by several authors are recognized, such as the arithmetic mean of Ramanathan and Ganesh (1994) or the geometric mean of Aczél and Saaty (1983). On the other hand, other methods are distinguished related to obtaining group preferences, among them the models proposed by Wang and Fan (2007), Shih *et al*., (2007) and Huang and Li (2010).

For our aggregation, the model proposed by Linares and Romero (2002) will be used, having into account the advantages it offers meaning that its solution is given by the medium, therefore, it is less affected by the incidence of data or anomalous findings that in these cases occurs frequently. Its analytical formulation is defined as follows:

$$Min\sum_{i=1}^{q}\sum_{k=1}^{N_j}\left(n_{ik}+p_{ik}\right)^{\pi} \qquad (1)$$

Subject to:

$$W_i^j + n_{ik} - p_{ik} = a_i^{kj} \quad i\in\{1,...,q\},\ \ k\in\{1,...,N_j\},$$

Where:

N_j: Number of members of the group

a_i^{kj} : Preference of the *k* member about the criteria *i*, *i* = 1, 2,…,*q*

W_i^j : Aggregated preference of the group about criteria *i*.

π : Parameter that indicates the metric.

I.The fifth step corresponds to the selection of the value referred to as pivot. Such selection is associated with the existence of real markets, considering it gives certain information on the different elements that compose it and thus its corresponding monetary value. This way, once you have the market information on the pivot value defined, it will be possible to use the traditional income updating method to perpetuate its value.

In these terms, the value obtained as DUV for the PNV is analyzed as a constant and perpetual income according to the use and exploitation as defined in the PNV. The analytical expression that responds to the income updating method described in Alonso and Iruretagoyena (1994); Sulista (2007) and Ortuño *et al*., (2007), is defined as:

$$V_A = \frac{R}{(1+i)}+\frac{R}{(1+i)^2}+...\frac{R}{(1+i)^{\infty}}$$

$$V_A = R\left[(1+i)^{-1}+(1+i)^{-2}+...\right] \qquad (2)$$

$$V_A = R\,(1+i)^{-1}.\frac{1}{1-(1+i)^{-1}}=\frac{R}{i}$$

Where:

V_A: Updated Direct Use Value ($DUV_{updated}$)

R: Income level (DUV obtained for the PNV)

i: Updating tax

I.By having the monetary value of the TEV component defined as pivot and the weight vector or weightings of each TEV component, then it is possible to calculate the value of the remaining components, taking into consideration that weight vector represents a weighting of the different components of TEV. Finally, with the estimation of each component, this indicator can be obtained. It is enough to use the definition given in the initial step to the TEV, which is structured by forming an aggregation of the individual components.

For this last step of the proposed multi-criteria decision modeling, the main concern is that the value be interpreted as a sum of partial values that represent its market value. The idea of †getting the TEV should not be interpreted as a market value, but as an approximation to the true value (Mogas *et al*., 2006; Aznar and Estruch, 2007) that can be associated with a certain natural environment, since elements are incorporated in the analysis have not a really market origin, precisely because they have not price.

RESULTS & DISCUSSION

This section provides a general characterization of the study area, which includes the identification of the main uses and exploitation of the PNV and subsequent application of the mathematical multi-criteria decision modeling by simultaneous conjugation of natural, social and economic components, as from the combination of methods such as AHP, the WGP and the income updating method, obtaining the estimation of an indicator of TEV to the PNV. The Viñales National Park (PNV) extends from NE to SW with a maximum width of 8 km to the center and a minimum of 2,5 to the western part, covering a length of 31 km. Its total area is 15010 ha, from which 11,120 belong to the central area and 3890 to the buffer zone (Fig. 1), which includes both, Viñales and a small part of the municipality of Minas de Matahambre (Corvea *et al*., 2006). The area comprising the PNV is framed in a physic-geographic region of mogotes, calcareous hills, slate heights and valleys between mountains, which form unique ecosystems characterized by a low level of human impact. Its high scene- aesthetic values, biodiversity and development of numerous karst forms motivate several specialists in their recognition as the capital of tropical karst. Also it is added the location of one of the largest cave systems in Latin America, confirming its exclusivity over other regions (Camargo, 2005).

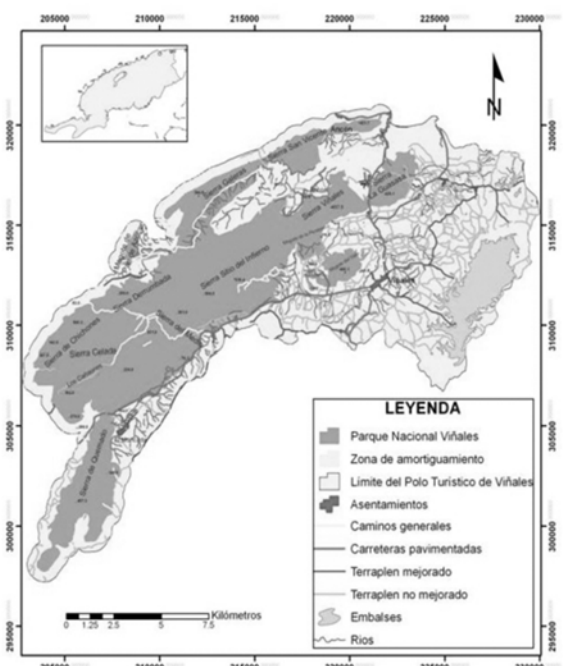

Fig. 1. Location and limits of the Viñales National Park, Pinar del Río, Cuba
Source: Gutiérrez *et al*. (2013).

The application of multi-criteria decision modeling approach has been developed according to the structure defined in the previous section, as follows:

I.The starting point consists in defining the main uses and exploitation which are present in the study area, which will include their DUV. These uses and exploitation are:

Tourism: The touristic activity in the territory stands out as the one with higher booming and growth, considering that the area is the main tourist destination in the province of Pinar del Río, and because of that, counts with a group of facilities for both hotel and extra -hotel providing touristic services.

Agricultural use: In the area comprising the PNV, the agricultural activity stands out as one of its main uses and exploitation, concentrated mainly in the cultivation of tobacco, to which the largest area is devoted, the production of assorted crops and livestock activity.

Forestry use: In the PNV important timber forests are identified, formed mostly by pine species concentrated on their slates heights, incorporating the production of wood, resin, charcoal, seeds, bags, treatments, apiculture, coffee, among others. As IUV, the scenic beauty of the landscape is identified, with special attention to the presence of Mogotes in the area (karst height relief), the production of biodiversity (endemic species of flora and fauna, soil types, rocks, etc.), historical and cultural wealth of the area, highlighting its archaeological values †(presence of bones and fossils remains), water abstraction and CO_2 sequestration. The OV is associated with the value given to the EGS group existing in the PNV considering, in an ambient of uncertainty, the possibility of future use. The VE is derived from the own knowledge of the existence of the group of EGS present in the PNV and as BV, defined as the importance attributed to the existence of the set of EGS existing in the PNV for the enjoyment of future generations, highlighting the awareness of the user to the possibility that the future generation can make use of the EGS.

II.The selection of the experts group, initially 29 people, responds to: forestry engineers, agronomists, economists, geographers, historians, botanists, specialists from the Ministry of Science, Technology and Environment of Cuba, academics and researchers with strong experience in protected areas.

The selection of experts was based on their self-assessment procedure, considering that this reflects their skills, being finally selected a group of 25. In this analysis were excluded from the study, experts 15, 17, 22 and 26, which classification was classified as low (0,35; 0,44; 0,42; 0,42) reason why it was considered its contributions to the research topic would not be significant.

III.The primary information obtained from questionnaires submitted to all selected experts; represent their corresponding subjective judgments about the importance offered for each TEV components. Such judgments expressed in paired comparisons matrix, allowed calculating their corresponding eigenvectors, as shown in following Table.

Table 1. Eigenvectors of the selected experts

Expert	DUV	IUV	OV	EV	BV	CR
1	0.01887	0.06329	0.08484	0.62475	0.20825	1,6%
2	0.02625	0.0645	0.15925	0.62475	0.12525	4%
3	0.0908	0.2574	0.48481	0.02789	0.13911	0%
4	0.04662	0.11089	0.17582	0.55561	0.11139	5%
5	0.017	0.02975	0.07813	0.14613	0.72888	2%
6	0.0182	0.0516	0.09719	0.13911	0.69389	0%
7	0.02625	0.0645	0.15925	0.62475	0.12525	4%
8	0.01745	0.04576	0.07979	0.7713	0.0857	2%
9	0.01887	0.06329	0.08484	0.0833	0.7497	1,6%
10	0.05428	0.0989	0.17982	0.22211	0.44489	1%
11	0.126	0.2997	0.4752	0.09	0.01	5%
12	0.10675	0.28	0.48825	0.0125	0.1125	2%
13	0.0182	0.0516	0.09719	0.13911	0.69389	0%
14	0.02625	0.0645	0.15925	0.24975	0.50025	4%
15	0.01887	0.06329	0.08484	0.71388	0.11912	1,6%
16	0.02722	0.0496	0.09018	0.13911	0.69389	1%
17	0.119	0.20825	0.54688	0.10938	0.01563	2%
18	0.02622	0.04158	0.0992	0.0833	0.7497	5%
19	0.0981	0.2781	0.5238	0.01	0.09	0%
20	0.0305	0.08	0.1395	0.5625	0.1875	2%
21	0.01313	0.03225	0.07963	0.21875	0.65625	4%
22	0.11329	0.19825	0.52063	0.13911	0.02789	2%
23	0.01616	0.0542	0.07264	0.09513	0.76187	1,6%
24	0.0175	0.04163	0.066	0.0875	0.7875	5%
25	0.02037	0.05344	0.09319	0.10413	0.72888	2%

Source: Own elaboration.

I.These individual preferences obtained with the AHP method, represented by its eigenvectors, were aggregated by the Weighted Goal Programming (WGP) for obtaining a normalized eigenvector that indicates the global weight of each values which constitutes the TEV.

As part of the aggregation process, a cluster analysis was performed to identify possible behavior patterns in each of the members and where these effects could be represented in the final aggregation. This analysis identified the presence of 3 clusters: 1 (experts 5, 6, 9, 10, 13, 14, 18, 20, 24, 27, 28, 29), 2 (experts 1, 2, 4, 7, 8, 16, 23) and 3 (experts 3, 11, 12, 19, 21, 25). Once identified, it was performed a profile associated with median for each value component by each cluster (Fig. 2) to characterize their behavior according to the relative importance or weight that each group provides for the component value.

Such perceptions were contrasted by parametric and nonparametric hypothesis tes, specifically an unvaried analysis of variance (Fisher test) and the Kruskal Wallis test, in order to verify whether there are significant differences for each component of value considering the cluster to which they belong , applying a significance level of 1%.

In Table 2, results of both tests are shown, which confirm that there really are significant differences in all value component by cluster ($p < a$).

The weightings obtained as a result of the solution of the WGP model are normalized. Its final aggregation is presented in Fig. 3.

I.Among the TEV components identified in the PNV, associated the existence of real market for the DUV, making it possible to find a corresponding monetary value in terms of net utility, as well as an update on their income levels. Obtaining this utility for the DUV meets an estimate for each of its uses (tourism, agriculture and forest). In this case, the data referring the year 2009 were taken as the basis, based on the specificities of such uses, and the availability of the required information.

Tourism: According to the Model 1398-03, created by the official institution of Cuba: Oficina Nacional de Estadística (ONE) it recognizes as hotel activity the following facilities: Hotel Los Jasmines, Hotel La Ermita,

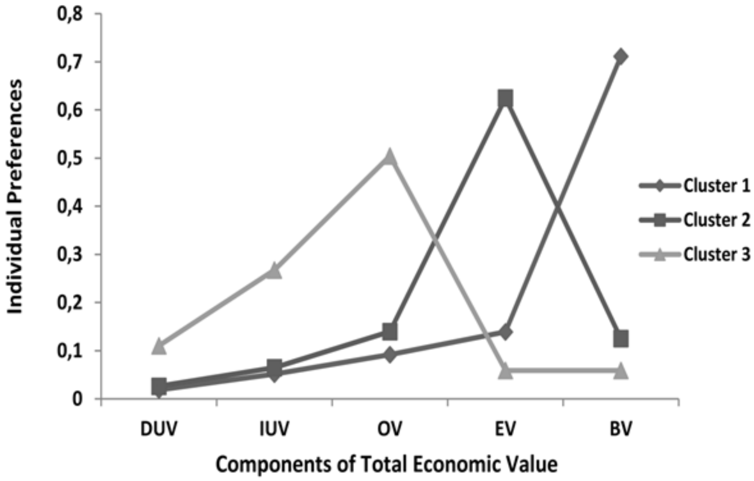

Fig. 2. Cluster profiles based on the medians
Source: Own elaboration

Table 2. Results of the cluster comparison

Test		DUV	IUV	OV	EV	BV
ANOVA univaried	F	130.250	130.393	290.108	173.049	156.059
	p	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Kruskal Wallis	p	<0.001	< 0.001	0.001	< 0.001	< 0.001

Source: Own elaboration

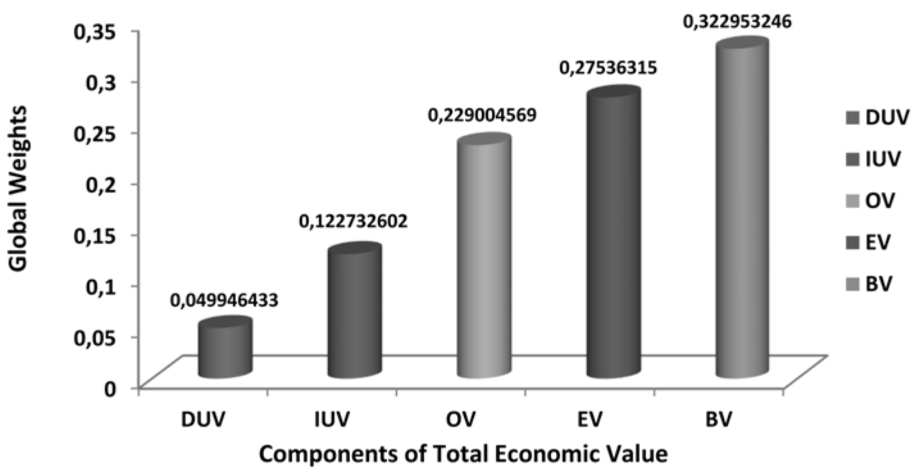

Fig. 3. Normalized aggregated weights of the experts group
Source: Own elaboration

Hotel Rancho San Vicente and Campismo Popular Dos Hermanas. The extra-hotel activity is in charge of: Sucursal Extra-hotelera Palmares Pinar del Río, Sucursal Caracol Pinar del Río, Agencia de Viajes Cubanacán S.A. Pinar del Río, Cubanacán Turismo y Salud Sucursal Pinar del Río, Artex S.A. Sucursal Pinar del Río and Unidad Empresarial de Base de Taxi de Turismo (Cubataxi).

Agricultural use: This achievement is in charge of Empresa Integral y de Tabaco Viñales, managed by Grupo Provincial de Tabaco Pinar del Río (TABACUBA). It identifies three fundamental activities: tobacco (sun tobacco and black tobacco), assorted crops: roots and tubers, vegetables, grains and fruit and livestock activity: meat and milk production in all types of stock farming.

Forestry use: This use corresponds to Grupo Empresarial Agricultura de Montaña (GEAM), specifically to the production units “Los Jazmines” and “Rancho San Vicente”, Empresa Apícola Cubana (UEB Apícola de Pinar del Río) and two basic production units: UBPC “El Moncada” and “Valle Ancón”. This use includes forestry (logging and non-logging), apiculture (honey, wax, propolis, jelly, queen and beehive) and coffee activity.
The information obtained from each of these uses enables obtaining a consolidated net utility (pesos) for the Direct Use Value as detailed in Table 3.

The Table 3 shows each of the contributions associated with the uses and achievements defined in the PNV, highlighting the agricultural use with a contribution of 64, 36%, followed by forestry use, with 21, 19% and the Tourism with a contribution of 14, 45%.

Once the DUV is obtained (1 579 101, 12 pesos), this income level is updated considering its importance for the economic valuation processes in protected natural areas. This value is analyzed as a constant and perpetual income, using the updating income method proposed by Alonso and Iruretagoyena (1994). The updating tax used corresponds to the formulation of Aznar and Estruch (2007), which results from the aggregation of the real risk -free rate and the rate of profit or premium risk. The real risk -free rate takes into account the rate of financing public debt of the state, which value is 1% for the Cuban case (Pérez , 2010) , less the value of the inter-annual inflation rate . Given the nature of the data , the last one (1,63%) is obtained by formulating the geometric mean corresponding to the december series (1996-2009) , obtained through data of the General Consumer Price Index (IPC) offered by Banco Central de Cuba (BCC , 2010) for the same period.

The benefit tax or premium risk represents the risk of not obtaining income from their uses and exploitation, so it takes a small value, which associated with the Cuban context, it reaches less than 2%, (between 1 and 2) which is exactly 1, 5%, based on the stability of price levels and other factors. Thus, the value of the updating tax is 0,87% and thus the updated DUV to the PNV is 181 505 875, 86 pesos.

I. Once the updated DUV for the PNV is obtained, using this value and the weight vector or global weightings resulting from individual preferences, obtained from the implementation of the AHP method and the subsequent aggregation for each TEV components using the WGP, it is necessary to calculate the remaining components of the TEV (IUV, OV, EV, BV) and the indicator of TEV.

Obtaining weight vector or global weightings for each TEV component permits the use of proportional allocation method, knowing the DUV value has been selected as pivot and thereby achieving the indicator of TEV estimation, as shown in Fig. 4.

This indicator of TEV for the PNV reaches 3 634 010 778, 35 pesos, that represents for its 15010 hectare, a value of 242 105, 98 pesos per hectare. Given its natural, economic and social incorporation of natural criteria, the TEV constitutes an approximation to the true value of this protected area, which represents a qualitative leap in the analytical framework of economic science, which promotes the protection and conservation actions of natural resources of the PNV. An important element, its generalization to other National Parks in the country, is also possible.

Table 3. Consolidated net utility for the Direct Use Value

Use	Net Utility
Tourism	**228 158,11**
- Hotel activity	(300 619,6)
- Extra-hotel activity	528 777,71
Agricultural use	**1 016 350**
- Collection and Benefits for Tobacco (ABT).	868 048
- Agricultural activity	148 302
Forestry use	**334 593,01**
- Forestry	355 095,11
- Apiculture	3 407,9
- Coffee	(23 910)
Total of Direct Use Value	**1 579 101,12**

Source: Own elaboration

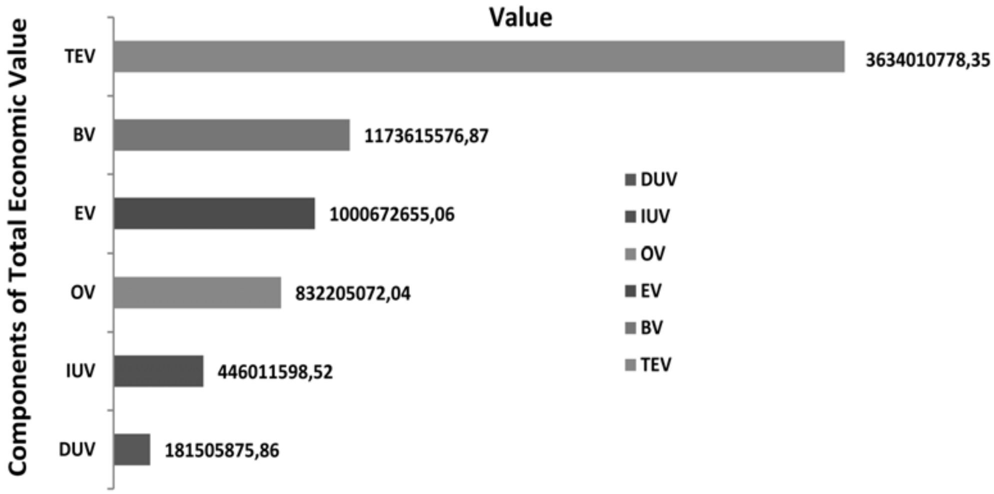

Fig. 4. Indicator of TEV for Viñales National Park (PNV)
Source: Own elaboration

CONCLUSION

The multi-criteria decision modeling used represents a contribution of economic science to decision-making processes associated with protected natural areas in search of a reordering of human behavior patterns. It involved a combination of methods such as the AHP and the WGP, with other traditional such as the updating income method.

The aggregation procedure (WGP) of individual preferences obtained with AHP helped to show how experts attributed greater importance to Non-use values †(0, 5983) on Use Values (0,4017). Obtaining updated DUV (181 505 875, 86 pesos) enabled the calculation of the indicator of TEV (3 634 010 778, 35 pesos), equivalent to 242 105, 98 pesos per hectare. It highlights the contribution of Non-use Values (NV), with a contribution of 2 174 288 231, 93 pesos (EV = 1 000 672 655, 06; BV = 1 173 615 576, 87), while Use Values (UV) provide 1 459 722 546, 42 pesos (DUV = 181 505 875, 86; IUV = 446 011 598, 52; OV = 832 205 072, 04).

These results are a starting point for the allocation and distribution of financial resources at macroeconomic level devoted to protected natural areas, promote direction and management processes of natural resources and contribute for formulation and implementation of strategic goals, environmental policies and management plans.

This indicator of TEV has to be seen not as a market value, but as an approximation to its true value. Its conception has a holistic and transdisciplinary character based on the simultaneous incorporation of natural, economic and social criteria.

ACKNOWLEDGEMENTS

The authors wish to thank the funding provided by the Federal Technological University of Paraná (UTFPR), especially the Postgraduate Program in Technology (PPGTE) and sponsored support of the Coordination for the Improvement of Higher Education Personnel (CAPES) in cooperation with the Ministry of Education of Cuba (MES), by providing a postdoctoral fellowship to Dr. Alain Hernandez Santoyo, under the Program CAPES / MES Cuba Docente, Edital No. 009/2013.

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